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with revisions

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TO ANS-3 MEMBERS AND ANSI/ANS 3.5 MEETING ATTENDEES:

Gentlemen:

Attached is the proposed revision of the Simulator Standard (ANSI 3.5). This revision will be reviewed at the ANS-3 meeting on March 5 and 6, 1980. Please send written comments to me for consideration at ANS-3 meeting.

The following individuals attended the meeting at Combustion Engineering February 20 and 21, 1980:

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Sincerely,

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NSE:hcv

NUCLEAR POWER PLANT SIMULATORS FOR USE IN OPERATOR TRAINING

1. SCOPE

This standard establishes the minimum functional requirements for nuclear power plant simulators for use in operator training. Simulators of test, mobile and research reactors, as well as reactors not subject to the U.S. Nuclear Regulatory Commission (NRC) licensing, and limited scope simulators intended for specialized training or familiarization are excluded. Minimum functional criteria are set for degree of simulation, performance and functional capability of the control room instrumentation and controls. Criteria for use of such simulators is not addressed in this standard.

1.1 Background Data

Operating and training practices differ among the various organizations which operate nuclear power reactors; however, common goals are assurance of safety, equipment availability, and efficient operations. It is intended that this standard provide flexibility in design and use of a nuclear power plant simulator.

It is intended that in meeting the criteria of this standard, the simulator will possess a sufficient degree of completeness and accuracy to meet the needs of industry and the requirements of NRC as described in Title 10, Code of Federal Regulations, Part 55, "Operators' Licenses", American National Standard for Selection and Training of Nuclear Power Plant Personnel, ANSI/ANS-3.1-1978, and American National Standard Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants, N18.7-1976/ANS-3.2.(1,2,3)[1]

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[1] Numbers in brackets refer to corresponding numbers in Section 6, References.

2. DEFINITIONS

backtrack. Restoration of the simulator to a previous set of conditions which have been automatically recorded at designated time intervals.

critical parameters.
(1) Those parameters that require direct and continuous observation to operate the power plant under manual control.
(2) Input parameters to plant safety systems.

freeze. A condition whereby the dynamic simulation will be interrupted and remain static until the simulator is taken out of the "freeze" mode, at which time dynamic simulation resumes.

Initialization condition. The preprogrammed condition prior to the start of the operation of the simulator.

malfunction. Failure or degradation in performance of plant equipment.

operator training. That training given to prospective and licensed (requalification) nuclear power plant reactor operators and senior reactor operators to meet the requirements of 10CFR55, ANSI/ANS-3.1-1978, and N18.7-1976/ANS-3.2. (1,2,3)

Real time. Simulation of dynamic performance in the same time base relationships, sequences, durations, rates and accelerations as the dynamic performance of the reference plant.

reference plant. The specific nuclear power plant from which the simulator control room configuration, system control arrangement and simulator data base is derived.

shall, should and may. The word "shall" is used to denote a requirement; the word "should" to denote a recommendation; and the word "may" to denote permission, neither a requirement nor a recommendation.

simulator data base. The "simulator data base" may be predicted data, plant design data, or it may include actual reference power plant performance data.

snapshot. The instantaneous storage of existing conditions at any selected point in time. The stored condition then becomes a temporary initialization point and may be called up repeatedly.

3. GENERAL REQUIREMENTS

The nuclear power plant simulator is intended to be used primarily for training device to provide initial and requalification training for nuclear power plant operators. The simulator may also be used as an examination tool. It shall provide complete and accurate simulation of control room equipment, plant systems, and plant operation as described in the following paragraphs. The extent of simulation shall allow the operator to fully participate in appropriate plant evolutions and permit control of unusual transients to a conclusion.

3.1 Simulator Capabilities

The response of the simulator resulting from operator action, automatic plant controls and inherent operating characteristics shall be realistic to the extent that within the limits of the performance criteria the operator shall not observe a difference between the control room indications of the simulator and the reference plant.

3.1.1 Normal Plant Evolutions

The simulator shall be capable of simulating continuously, and in real time, plant operations of the reference nuclear power plant. The simulator shall calculate plant system parameters corresponding to particular operating conditions, display these parameters on the appropriate instrumentation, and provide proper alarm or protective system action, or both. The minimum evolutions that the simulator shall be capable of performing, using only operator action normal to the reference plant, the following:

Plant startup - cold (refueling conditions of temperature and pressure) to hot standby.

Nuclear startup from hot standby to rated power.

Turbine startup and generator synchronization.

Reactor trip followed by recovery to rated power.

Operations at hot standby.

Load changes (manual and automatic control).

Power operations with less than full reactor coolant flow.

Plant shutdown and cooldown to cold (refueling) conditions.

Core physics testing after load or reload.

Operator conducted surveillance test on safety-related equipment or systems.

3.1.2 Plant Malfunctions

The simulator shall be capable of simulating in real time a minimum of seventy-five (75) abnormal and emergency conditions resulting from malfunctions to demonstrate inherent plant response and functioning of automatic plant controls. Each type of ~~accident~~ analyzed in the reference plant safety analysis report which results in observable indications on control room instrumentation shall be simulated. The remainder of the minimum number shall consist of a variety of malfunctions associated with the electrical, auxiliary, engineered safety systems, steam systems, reactor coolant, instrumentation, and control. Where applicable to the malfunction, the simulator shall provide the capability for the operator to take action to recover the plant or mitigate the consequences, or both. Plant response to the malfunctions shall be carried out to a reasonable operating condition, as determined by an analysis of the training objective of each malfunction. The abnormal and emergency conditions listed below shall be included, as applicable to the type of reactor.

(1) Loss of coolant

(a) including significant PWR steam generator leaks

(b) inside and outside primary containment

(c) large and small reactor coolant breaks including demonstration of saturation condition

(2) Loss of instrument air

(3) Loss of electrical power (and/or degraded power sources)

(4) Loss of forced core coolant flow

(5) Loss of condenser vacuum

(6) Loss of service water or cooling individual component

(7) Loss of shutdown cooling

(8) Loss of component cooling system or cooling to individual components

(9) Loss of normal feedwater or normal feedwater system failure

(10) Loss of all feedwater (normal and emergency)

(11) Loss of protective system channel

(12) Mispositioned control rod or rods and rod drops

(13) Inability to drive control rods

(14) Fuel cladding failure or high activity in reactor coolant or offgas

(15) Turbine trip

(16) Generator Trip

(17) Malfunctions in automatic control system(s) which affect reactivity and core heat removal

(18) Malfunctions of reactor coolant pressure/volume control system

(19) Reactor trip

(20) Main steam line break (inside or outside containment)

(21) Nuclear instrumentation failure(s)

(22) Process instrumentation, alarms, and control switch failures

p 9.
a) To systems unique to safety AC and/or DC
b) To Sys not unique to safety AC/and/or DC

3.2 Control Room Environment

3.2.1 Control Panels

The control panel physical arrangement, size, and front panel mounted components shall closely parallel the reference plant. Plant information shall be displayed to the operator in the same form that it is available in the reference plant; i.e., meters, recorders, etc. Controls, meters, alarms, recorders, switches, annunciators, controllers and other components that would function during normal and abnormal operations as defined in 3.1.1 and 3.1.2 shall be furnished in the simulator. These panels shall be functional to the extent that control manipulations performed during normal, abnormal, and emergency evolutions are operable.

3.2.2 Control Room Environment

Consideration shall be given to simulating as much of the control room environment as is reasonable and practical, for example, turbine noise, control rod step counter noise, flooring and lighting. Communication systems that a control room operator would use to communicate with an auxiliary operator or other support activities shall be operational to the extent that the simulator instructor, when performing these remote activities, shall be able to communicate over the appropriate communication system.

3.3 Systems to be Simulated and the Degree of Completeness

3.3.1 Systems Controlled from the Main Control Panels

The inclusion of systems of the reference plant and the degree of simulation shall be to the extent necessary to perform the reference plant evolutions described in 3.1.1 and the malfunctions described in 3.1.2. It shall be possible to perform these control manipulations and observe plant response as in the reference plant.

3.3.2 Systems Operated or Functions Controlled Outside of the Control Room

The systems that are remotely operated or that provide some input to the main simulation model and are necessary to perform reference plant

evolutions described in 3.1.1 and malfunctions described in 3.1.2 shall be simulated. It shall be possible to interface with the remote activity in the same manner as in the reference plant.

3.4 Simulator Training Capabilities

The simulator shall contain:

3.4.1 Initial Conditions:

The simulator shall possess a minimum capability of 20 initialization points. At the time of commencement of operations of the simulator in the training program, a minimum of 10 initialization points shall be operational and shall include a variety of plant operating conditions and fission product poison concentrations. Various times in core life shall be included in making use of the additional initialization capability.

3.4.2 Malfunctions

It shall be possible to conveniently insert and terminate the plant malfunctions specified in 3.1.2. The simulator shall be capable of simulating simultaneous and/or sequencial malfunctions, if these malfunctions can be expected to occur by design or operational experience. The introduction of a malfunction shall not alert the operator to the impending malfunction.

3.4.3 Other Control Features

The simulator shall have the capability of freezing simulation. In addition, consideration should be given to incorporation of fast time, slow time, backtrack, and snapshot capabilities.

3.4.4 Instructor Interface

The capability shall be provided for the instructor to act in the capacity of auxiliaty or other operators remote from the control room, for example, change the operating condition of valves, breakers or other devices.

4. PERFORMANCE CRITERIA

4.1 Steady State Operation

The simulator accuracies shall be related to rated full power values. The parameters displayed on the control panels that may have the instrument error added to the computed values. During testing the error shall be determined at several points over the power range.

(1) The simulator instrument error shall be no greater than that of the comparable meter, transducer and related instrument system of the reference plant.

(2) Principal mass and energy balances shall be satisfied. Examples are:

Reactor power indication to generated.

Primary system temperature to steam generator pressure.

Feedwater flow to reactor power.

Mass balance of pressurizer.

Mass balance of steam generator.

The simulator computed values for steady state, full power, automatic control operation shall not change (drift) by more than $\pm$ 2% over a 60-minute period.

(3) The simulator computed values of critical parameters shall agree with the reference plant parameters to within $\pm$ 2%. Examples of the critical parameters are:

Reactor power.

Reactor hot and cold leg temperatures.

Feedwater flow.

Steam pressure.

Generated electrical power.

Recirculation flow.

Primary system pressure.

(4) The calculated values of noncritical parameters pertinent to plant operation, that are included on the simulator display panels, shall agree with the reference plant to within $\pm$ 10% or shall not detract from training.

4.2 Transient Operation

4.2.1 Tests shall be conducted to prove the capability of the simulator to perform correctly during the limiting cases of those evolutions identified in 3.1.1 and 3.1.2 of this standard. Acceptance criteria for these tests shall: (a) Where applicable, be the same as plant startup test procedure acceptance criteria (within the limits of the simulators' accuracies), (b) Require that the observable change in the parameters correspond in direction and magnitude to those expected during the simulated transient in the simulated time period and not violate the physical laws of nature, (c) Require that the simulator shall not fail to cause an alarm or trip if the reference plant would have caused an alarm or trip and conversely the simulator shall not alarm or trip if the reference plant would not alarm or trip.

4.2.2 Malfunctions and transients not tested shall be compared to design calculations or other available information and shall meet the above acceptance criteria.

5. SIMULATOR UPDATE

5.1 Simulator Data Base Updating

Simulator constructed within the guidelines of this standard are based on a data base of actual or predicted plant configuration and performance. The simulator owner, operator shall maintain an accurate and current data base on the reference plant. On each change to the reference plant each change shall be evaluated and appropriate modifications made to the simulator. Certain changes may not be required to be made to the simulator with appropriate engineering evaluation. At the time of modifications the simulator data base shall be updated and remain the technical basis for the simulator. The data base for simulators whose reference plant has been in commercial operation for more than 18 months prior to simulator training availability shall be actual reference plant performance data. For those simulators utilized for training not included in the above the data base shall be updated to actual plant data within 18 months after the reference plant is in commercial operation or simulator is available whichever is later. ✓

5.2 Simulator Updating

The reference plant control room environment controls, meters, alarms, recorders, switches annunciators, controllers and other components shall be reviewed annually to evaluate compliance with Section 3.2. Updating in response to this review shall be completed prior to the next annual review. An evaluation of necessary simulator modifications shall be made for planned major modifications to the reference plant which effect simulator compliance with sections 3.2 and 3.3.

5.3 Use of Feedback for Updating

The simulator shall be updated by feedback from instructors, reactor operators from the reference plant, and operator trainees. This feedback should include identified problems with the simulator, and recommended additional simulator capabilities. The feedback should be reviewed by the training and operations organizations.

5.4 Simulator Performance Testing

Simulator performance shall be established by the preparation of a simulator acceptance test, conducting the test, and comparing the simulator's performance with the appropriate data base as determined in Section 5.1 above, within the requirements of Section 4. The performance test and report shall be conducted on each of the following occasions:

(1) Initial construction and acceptance for training

(2) When the simulator is updated as required in Section 5.1 and 5.2. When a limited change is made a specific performance test on the affected systems and components shall be performed or every 4 years whichever is lesser. Performance test shall be performed no less often than at 4 year intervals.

AMERICAN NATIONAL STANDARD FOR NUCLEAR POWER PLANT SIMULATORS

FOR USE IN OPERATOR TRAINING ANSI/ANS-3.5-1979

APPENDIX A

Procedure for Documenting Simulator Performance

The purpose of this procedure is to provide a standard report format for demonstration of a simulator's conformance to the requirements of ANS 3.5. It is intended that the documentation provide a sufficient basis for verification of simulator performance. This documentation shall be maintained at the simulator facility.

1. SIMULATOR INFORMATION

   1.1 General

   1.2 Control Room

   1.3 Instructor Interface

   1.4 Operating Procedures for Simulated Plant

   1.5 Changes Since Last Report

2. SIMULATOR DATA BASE

   2.1 System Descriptions

   2.2 Physics Data

   2.3 Steady State Operating Conditions

   2.4 Transient Operating Conditions

   2.5 Malfunction Operating Conditions

   2.6 Design Analysis Data

   2.7 Protective and Control Setpoints

   2.8 Interlock and Control Logic

3. SIMULATOR TESTS

   3.1 Normal Operations

   3.2 Abnormal Operations

   3.3 Personnel Conducting Tests

   3.4 Anticipated Upgrading

1. SIMULATOR INFORMATION

This section contains "name plate" data, control room information, and instructor interface features. The intent is to provide familiarization with the specific simulator and its general applicability as an operator training vehicle. (Note: The symbol, §, denotes references to ANSI/ANS 3.5)

1.1 General

Owner/Operator/Manufacturer - Initial Operating Date -

Reference Plant - Initial Operating Date -

Type of Report (Initial Operation, Initial Update, Subsequent Update) -

1.2 Control Room

Physical arrangement of control room equipment.

Comparison to Reference Plant.

Equipment not in Simulator Control Room.

(e.g., Security system desk.)

Equipment included in simulator control room.

(e.g. Nuclear Instrument Racks, System Test Cabinets).

1.3 Instructor Interface

Location of instructor controls.

Simulator Initial Condition List (§ 3.4).

Control provided for systems operated/controlled from outside control room. (§ 3.3.2)

List of malfunctions (§ 3.1.2)

Special instructor/training features for Simulated Plant (§ 3.1.1)

1.4 Operating Procedures for Simulated Plant

Indicate significant difference ~~between~~ from reference plant procedures.

Identify special procedures used only for simulator testing.

1.5 Changes Since Last Report

List by category.

2. SIMULATOR DATA BASE

Data base for testing will be the existing data base established and maintained to define the reference plant and the simulator basis and model construction and additional items to further establish the performance of simulators. This section contains details which are pertinent to the reference plant including design analysis data, plant parameters, plant system description, plant operations and testing data. The intent is to present the complete data base from which the simulator was designed, on which upgrading has been and may be based, and with which correlation will be shown.

2.1 Steady State Operating Conditions

1. Description of Steady State condition (e.g., hot shutdown, 20% load, etc.) including equipment lineup.
2. Source of data (e.g. design data, reference plant and date).
3. List of the values of all critical parameters including system I.D. and source (e.g. meter tag no., computer printout, etc.)

2.2 Transient Operating Conditions

1. Description of transient (e.g. turbine trip, reactor trip, loss of offsite power, etc.) including equipment lineup.
2. Source of data.
3. List of the values of pertinent critical parameters at reasonable frequency before, during and after transient.
4. Provide limits of applicable plant startup acceptance test criteria.
5. Note operating procedure sequence being followed and any abnormal conditions.

2.3 Significant Plant Occurring Event (Optional)

1. Description of event including plant equipment lineup.
2. Source of data.
3. Values of critical parameters observed or calculated before,

during and after the transient.

2.4 Design Analysis Data

1. Supporting analytical data for the accident conditions simulated but not observed in an operating plant.

3. SIMULATOR TESTS

These are the guidelines test documentaiton. The intent of this test is to demonstrate compliance with the requirements of ANSI/ANS 3.5 by comparison of simulator performance with the data base in Section 2.

3.1 Normal Operations

1. Compare control room equipment with data base. List changes in reference plant and simulator since last report.
2. Demonstrate that the simulator initial conditions correspond to those listed in Section 1.3.
3. Perform the plant evolutions required in § 3.1.1 of the standard.
4. Maneuver the simulated plant to the steady state operating conditions approximately four different power conditions for which data are available in Section 2.3. At each condition perform the applicable mass and energy balances. Record the computed value and displayed value of all critical parameters. Show that these values fall within the limits given in § 4.1 of the standard.
5. Operate the simulator at steady state and rated power, record computed all critical parameters computed values at ten minute intervals for a 60-minute period. Show that these values fall within the limits given in § 4.1 of the standard.
6. Maneuver the simulated plant through the transient operating conditions for which data are available in Section 2.4. Record the set of parameters for which data were obtained in a similar manner. Verify that the performance of the simulated plant agrees with the available data base with in tolerance specified in 4.2 of the standard.

3.2 Abnormal Operations

1. Initiate the event sequence referenced in Section 2.5 for

which data are available from an operating plant. If this is not a standard simulated condition, explain the method used to initiate the malfunction condition for the test. Compare the simulated and observed data and show that they meet the criteria specified in § 4.2 of the standard.

2. Test each of the 75 malfunction conditions required to meet Section §3.1.2. Record appropriate critical parameters and show that they agree with the criteria specified in § 4.2 of the standard.

3.3 Plans for Upgrading

Describe plans for upgrading the training simulator to correct discrepancies with the performance criteria.

AMERICAN NATIONAL STANDARD FOR NUCLEAR POWER PLANT SIMULATIONS

FOR USE IN OPERATOR TRAINING ANSI/ANS-3.5

APPENDIX B

IMPLEMENTATION SCHEDULE

The adoption of this standard will make it applicable to all simulators which are already being utilized in approved operator licensing preparation and requalification programs. It is expected that the demonstration of simulator performance would be initially completed as a part of the acceptance test. The implementation of Section 5 of the standard shall be demonstrated through the completion of Appendix A. The minimum acceptable schedule is:

Section 1., Simulator Information and Section 2, Simulator Data Base, shall be complete within one year of the standard.

Section 3, Simulator Tests, shall be conducted and initial documentation within two years. Deviation from the data base shall be corrected and the simulator shall be in full compliance within three years.